The Maximum Efficiency of Photosynthesis: A Rediscovery

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IT WAS REPORTED in 1923 (*4*) that in photosynthesis 4 light quanta, absorbed by chlorophyll in green cells, can produce one molecule of oxygen under favorable conditions. This means that with red light about 65 percent of the absorbed radiant energy can be transformed into chemical energy. Quanta of red light are of low energy (~ 44,000 cal/mole) and several such quanta must therefore cooperate to develop one molecule of oxygen, which requires ~ 112,000 cal/mole. No analogy is known in the nonliving world, where most photochemical reactions, although simpler and effected by quanta of higher energy, are far less efficient in energy transformation, and are indeed usually exothermic. It became clear that an unknown principle, active in nature, awaited elucidation by physics and chemistry.

It is well known how the anticipated study of this new principle was interrupted about 1938, when almost every investigator in the field came to accept as the maximum efficiency of the energy transformation low values of 20 to 25 percent, that is to say, quantum values of 10 to 12 with red light. The development of this revocation has been extensively summarized in a book just published in the last few months by James Franck and Walter Loomis (*1*) and contributed to by a series of investigators.

We have reinvestigated the problem and have rediscovered the high efficiency of energy transformation in photosynthesis. The data obtained are conclusive.

In the course of this reinvestigation the methods have been simplified and improved in such a way that determinations of quantum requirements are no longer the privilege of the few. On the contrary, anyone who has a suitable light source and simple manometric equipment can now determine quantum requirements and convince himself that in green cells the greater part of the absorbed light energy can be transformed into chemical energy (see Addendum).

Improvements in Technique

Culture of cells. A strain of *Chlorella pyrenoidosa,* used in various institutes for many years and originally isolated and identified by Florence Meier, of the Smithsonian Institution, was cultivated in 300-ml gas wash bottles of the Drexel type. The culture medium was 5 g $MgSO_4 \cdot 7\,H_2O$, 2.5 g KNO_3, 2.5 g KH_2PO_4, 2 g NaCl, and 5 mg $FeSO_4 \cdot 7\,H_2O$, dissolved in 1000 cm^3 of nonsterilized well water (pH 4.5 to 5.0). Approximately 100 mm^3 of cells suspended in 200 cm^3 culture medium was added to each bottle, and aerated with 5 percent CO_2 in air so rapidly (~ 500 ml/min) that no sedimentation of the cells occurred. They were illuminated with a 100-w incandescent lamp that raised the temperature in the bottles to 25–30° C. After several days, when the cells had multiplied several fold, and the pH had risen 0.5 to 1 unit, the cultures were used for yield experiments. Such cells gave stable respiration values and high yields without exception. This culture method, which had been employed by one of us (D.B.) for many years in Washington, was found to be an important improvement over the method of 1923 (*4*) followed by most later investigators but which we have now discarded. In the earlier method, slowly aerated cells settled down in Erlenmeyer flasks in sediments that were inade-

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quately illuminated and inadequately supplied with carbon dioxide and oxygen until reshaken up.

Manometry. Approximately 300 mm³ of cells, resuspended in 7 cm³ of a fresh culture medium of pH 4.9, were put into rectangular vessels of 14 to 20 cm³ volume and saturated with 5 percent CO_2 in air. Two vessels were used to determine, as described in 1924 (*3*), the oxygen as well as the carbon dioxide exchange. The gas volumes in the two vessels were different, but the volumes of the solutions and therefore the concentrations of the cells were equal. The vessels were shaken at 20° C by horizontal motion, with an amplitude of 2 cm and a frequency of 150 per min. In spite of this rapid motion, which moved the vessels 600 cm per minute, no splashing or foaming occurred, even in experiments of more than 20 hr duration. It was a further improvement owing to this motion that physical transition effects were not observed upon change from dark to light and vice versa, that is, the gas equilibration was virtually perfect for our purposes.

The well known requirement of the two-vessel method, that the metabolism in the two vessels must be identical ($x_{O_2} = x'_{O_2}$ and $x_{CO_2} = x'_{CO_2}$) was complied with by eliminating a dangerous differential time factor as nearly as possible. The light beam of measured intensity (630 to 660 mμ) was shifted by a mirror alternately from one vessel to the other at intervals of 10–60 min or these vessels were shifted alternately into and out of the fixed light beam. Thus in every case the one vessel was illuminated when the other vessel was dark and vice versa, and when many light and dark periods followed each other and the pressure changes of all dark periods and of all light periods were summed, the metabolism in the two vessels was virtually identical for the same periods of elapsed time. The total pressure changes effected by light were usually of the order of magnitude of +20 to +50 mm. These figures were differences between two rates of oxygen consumption (negative pressure changes) in the experiments with noncompensated respiration. But when the respiration was compensated by white light (see following section) the figures +20 to +50 mm were the directly observed positive pressure changes, produced by the added red light. To measure such great pressure changes simple Haldane-Barcroft blood-gas manometers could be used instead of the special differential manometer heretofore employed.

Measurement of the quantum intensity. The bolometer used in 1923 was replaced by the chemical actinometer described a few months ago (*6*). This resulted not only in a simplification but in an improvement in accuracy. When the oxygen produced by the red light had been measured, the vessel containing the cells was replaced by a similar vessel containing 2 mg of ethyl chlorophyllide, 200 mg of thiourea and 7 cm³ of pyridine, with tank oxygen as the gas phase. The light absorption being complete in the cell suspension as well as in the ethylchlorophyllide solution, the quantum requirement per molecule oxygen was obtained by the very simple equation:

$$\frac{1}{\phi} = \frac{h \cdot \nu}{O_2} = \frac{O_2 \text{ consumed by the actinometer}}{O_2 \text{ produced by the cells}},$$

where the consumption and the production of the oxygen must be calculated for equal time periods.

Complete absorption is the only method so far devised by which the *absorption* of the light and the *action* of the light can be measured manometrically under the same conditions. Thus far all manometric determinations of quantum requirements using incomplete absorption are contradictory and uncertain. On the other hand, the main objection against the method of complete absorption was the existence of too great a respiration relative to the measured light action; this objection is no longer valid because today respiration can be eliminated by compensating with white light or components thereof (see the following section).

A New Principle

Let us consider a *Chlorella* suspension, shaken in a beam of red light that is absorbed completely, to be a machine that transforms light energy into chemical energy. The efficiency of this machine will be known if we know the light energy entering the vessel and the amount of oxygen developed in it, one mole of oxygen being equivalent to the production of about 112,000 cal. No theory of the mechanism of this energy transformation can alter the observed result of such an efficiency determination.

Yet there are possible objections to be answered. When at low light intensities respiration still exceeds photosynthesis, then our machine does not produce a net gain of chemical energy, and it might be considered that the light merely inhibits the loss of chemical energy. Since respiration is a catalytic process, conceivably its inhibition by light could be merely anticatalytic, requiring no expenditure of energy. Hence the calculation of the efficiency might be safe thermodynamically only when the light intensities are so high that oxygen is in fact given off from the cell suspensions into the gas space.

To comply with this requirement we illuminated the cell suspensions with white light (of nonmeasured intensity) over the greater part of the vessel surface, the light intensity per unit area being relatively small, but the influx of light energy through the total area

of the vessel being sufficient to compensate or overcompensate the respiration of the cell suspensions. As the compensating light intensity we define here that light intensity which effects the result that no oxygen enters or leaves the cell suspension. It is very likely that in this state the oxygen exchange of all cells in the suspension is zero, owing to the rapid motion of the cells. It is obvious that our compensating light intensity varies with the amount of cells in the vessel and is not to be confused with the compensating light intensity for very thin cell suspensions.

When the steady state in the white light was reached, a beam of red light of measured intensity was sent through the bottom of the vessel into the cell suspension, the cross section of the beam being 3 cm^2 and the total energy flux about 0.25 microeinsteins/min. It was completely absorbed in the cell suspension. The increase of positive pressure effected by the red light and the intensity of the red light were the two magnitudes from which the efficiency of the energy transformation of the added red light was calculated. The efficiency so found with red light proved to be as high, at and several fold above the compensation point with white light, as the efficiency at zero or low white light intensities below the compensation point (3 to 5 quanta per O_2 molecule developed; see Examples 1–5).

This result raised the whole level of certainty in this field of investigation, and is probably owing in large part to the rapid motion of a great amount of cells. The time of illumination with red light of relatively high intensity must be so short for every cell that no Blackman or other dark reaction limits the action of the light; in other words the product of light intensity and time ($i \times t$) must be too small to alter the concentrations of dark reactions. The observed efficiency is, of course, a fact that is independent of all theories about what happens in the cell suspensions, chemically or physically.

Another factor that might limit the certainty of efficiency determinations is time of illumination. The shorter the time periods, the greater is the danger that the energy of some dark reaction contributes to the oxygen production. The longer the time periods, the more certain are we that we have reached the thermodynamically desirable state in which the concentrations of all cell constituents are kept constant.

From 10 min in 1923 (*4*) and 15 min in 1948 (*5*) we have now extended the time periods to more than 20 hr of continuous illumination with white light, producing continuous positive pressure, and have varied the periods of the efficiency determinations with added red light from 5 to 60 min. This great improvement was possible because the horizontal motion of the rectangular vessels did not damage the photosynthetic capacity of the cells and because the white light, when it overcompensated respiration, stabilized the chemical conditions in the cells. In fact, the efficiency of the energy transformation has now been measured under the conditions of growth, so that very likely the experiments can be extended to any length of time.

Nonaction of Light on Respiration

If the manometric efficiency of the red light is the same when the respiration of the cell suspensions is noncompensated, compensated, or several fold overcompensated by added unmeasured white light, then obviously every theory should be rejected that assumes that light acts on the process of respiration anticatalytically or stoichiometrically. This conclusion has now been confirmed independently by the following type of experimentation:

A rectangular vessel was set up to contain NaOH and glass beads in two side arms, 300 mm^3 of cells in 7 ml of culture medium (pH 4.5–5) in the main compartment, and air in the gas phase. The vessel was shaken at 20° C slowly or rapidly, and in the dark or in the light. By changing the rate of shaking the steady-state pressures of CO_2 in liquid and gas phases were changed, but in the dark this had no effect on the observed rate of respiration. In the light, the rate of oxygen consumption decreased in the slowly shaken vessel; but in the rapidly shaken vessel, where the steady-state pressure of CO_2 was lower, *no action of light on the rate of oxygen consumption was observed* when the intensity of the light entering the vessel was about 0.25 microeinsteins/min, an intensity that with adequately high CO_2 pressures gave high photosynthetic efficiencies (3 to 5 quanta per molecule of O_2 developed). The shaking effect was reversible, the action of the light alternately appearing or disappearing with decreasing or increasing shaking rate.

The experiments may be extended to higher light intensities, but the higher the light intensity the more effective must be the removal of the carbon dioxide, for which the light and the alkali compete. The CO_2 pressure required to yield maximum respiration is clearly below that needed for effective photosynthesis, where CO_2 functions as substrate and not merely catalytically.

Such experiments prove that the light did not interfere with the process of respiration, either anticatalytically or stoichiometrically by reduction of intermediates. Light, when it compensated respiration, did so by producing oxygen, and because the gas exchange of photosynthesis happens to be the reverse of the gas exchange of respiration. Thus a question, old as the science of photosynthesis, has been answered by the most simple of experiments.

EXAMPLES

1. Manometric pressure changes effected by red light when respiration was not compensated by white light. Two-vessel method, culture medium pH 5, 5% CO_2 in air. 20° C.

Vessel I $v = 13.913$, $v_f = 7.00$

Vessel II $v' = 17.993$, $v'_f = 7.00$

Actinometer 5.4 mm³ O_2/min

Vessel I	Vessel II
10 min dark −26 mm	10 min dark −12 mm
" " " −23 "	" " " −10 "
" " " −23 "	" " " −11 "
" " " −23 "	" " " −11 "
40 min dark −95 mm	40 min dark −44 mm
10 min light −17 mm	10 min light −7 mm
" " " −15 "	" " " −7 "
" " " −14 "	" " " −7 "
" " " −15 "	" " " −7 "
40 min light −61 mm	40 min light −28 mm
Light action +34 mm	Light action +16 mm

$$\left.\begin{array}{l} x_{O_2} \text{ in 40 min} + 51.6 \text{ mm}^3 \\ x_{CO_2} \text{ in 40 min} - 53.7 \text{ mm}^3 \end{array}\right\} \gamma = \frac{CO_2}{O_2} = -1.04$$

$$\frac{1}{\phi} = \frac{h\nu}{O_2} = \frac{40 \cdot 5.4}{51.6} = 4.2$$

2. Manometric pressure changes effected by red light at 20° C, when respiration was overcompensated by white light. pH 5.0. 5% CO_2 in air. Actinometer for red light 5.4 mm³ O_2/min.

Vessel I $v = 13.913$, $v_f = 7.00$

Vessel II $v' = 17.993$, $v'_f = 7.00$

Vessel I	Vessel II
5 min white +18.5 mm	5 min white + red +22 mm
" " " +18.0 "	" " " " +22.5 "
" " " +16.5 "	" " " " +22 "
" " " +17.5 "	" " " " +20.5 "
" " " +17.0 "	" " " " +23.0 "
25 min white +87.5 mm.	25 min white + red +110 mm.
Action of red light +22.5 mm in 25 min.	
Vessel II	
5 min white +14 mm	5 min white + red +15 mm
" " " +14 "	" " " " +16.5 "
" " " +12.5 "	" " " " +16.5 "
" " " +14.0 "	" " " " +14.0 "
" " " +11.5 "	" " " " +15.0 "
" " " +12.0 "	" " " " +14.5 "
30 min white +78 mm.	30 min white + red +91.5 mm.
Action of red light +13.5 mm in 30 min.	

$$\left.\begin{array}{l} x_{O_2} \text{ in 25 min} + 30.3 \text{ mm}^3 \\ x_{CO_2} \text{ in 25 min} - 27.2 \text{ mm}^3 \end{array}\right\} \gamma = \frac{CO_2}{O_2} = -0.9$$

$$\frac{1}{\phi} = \frac{h\nu}{O_2} = \frac{25 \cdot 5.4}{30.3} = 4.5$$

For the same culture, when the respiration was not compensated by white light, we obtained

$$\frac{1}{\phi} = \frac{h\nu}{O_2} = \frac{60 \cdot 5.4}{70.4} = 4.6$$

and $\gamma = \frac{CO_2}{O_2} = -0.8$

3. Manometric vessels continuously illuminated for 27 hr by white light of approximately compensating intensity. $\frac{1}{\phi} = \frac{h\nu}{O_2}$, for the added red light, at the beginning and end of the experiment.

In hours 1 to 4, respiration compensated, $\frac{1}{\phi} = 4.5$ ($\gamma = -1.0$)

In hours 20 to 22, respiration compensated, $\frac{1}{\phi} = 4.5$ ($\gamma = -1.0$)

In hours 27 to 28, respiration not compensated, $\frac{1}{\phi} = 3.5$ ($\gamma = -1.27$)

4. Comparison of same culture in M/10 carbonate buffer (pH 9) and in culture medium (pH 5).*

Red light, 630–660 mμ. $I \sim 0.25$ microeinsteins/min 20° C.

Quantum requirement $\frac{1}{\phi} = \frac{h\nu}{O_2}$ for the added red light.

In carbonate buffer, respiration compensated by white light, $\frac{1}{\phi} = 10.5$

In culture medium, respiration compensated by white light, $\frac{1}{\phi} = 3.9$ ($\gamma = -1.04$)

In carbonate buffer, respiration not compensated $\frac{1}{\phi} = 9.8$

In culture medium, respiration not compensated $\frac{1}{\phi} = 3.6$ ($\gamma = -1.18$)

In carbonate buffer, respiration not compensated $\frac{1}{\phi} = 11.3$

* It may be gathered from this example that the efficiency in the unnatural carbonate buffer is only a fraction of the efficiency in culture medium. Many investigators believed that the efficiencies in both solutions were equal, and this was one of the reasons why the quantum requirement of 4 was denied by them and the figures 10 to 12 accepted as maximal.

5. Results by 2-vessel method for a series of experiments that were carried out from May 26 to June 16 of this year, at 20° C, in culture medium at pH 5, with an intensity of red light not exceeding 0.25 microeinsteins/min. No experiment is omitted.

	$\frac{1}{\phi}$	γ
	$\left[\frac{h\nu}{O_2}\right]$	$\left[\frac{CO_2}{O_2}\right]$
	3.2	−1.08
	4.6	−0.80
	4.5	−0.90*
	3.9	−1.04
	3.6	−1.18
	4.2	−0.97
	2.8	−1.16
	2.8	−1.23
	2.5	−1.25
	4.5	−1.00†
	4.7	−0.93†
	3.5	−1.27
	4.2	−1.00
	3.0	−1.33
Average	3.7	−1.08

* Respiration overcompensated by white light from above.
† Respiration compensated by white light from above.

It may be gathered from Example 5 that the quantum requirement for carbon dioxide consumed can be equal to or somewhat greater or smaller than the requirement for oxygen produced. For we have

$$\frac{1}{\phi} \cdot \frac{1}{\gamma} = \frac{h\nu}{O_2} \cdot \frac{O_2}{CO_2} = \frac{h\nu}{CO_2},$$

a magnitude which here for the first time, to our knowledge, has been determined in nutrient medium at low pH (about 5), and has been found to approximate $\frac{h\nu}{O_2} = 3$ to 5.

Yet the quantum requirement for oxygen is the more fundamental energy measure, because there is only one reaction in photosynthesis that produces oxygen—the photochemical reaction (decomposition of water); but there are many different dark reactions that consume carbon dioxide to form a great variety of products. Thus if, as an extreme case, oxalic acid were formed from water and carbon dioxide γ for this compound would be -4 and the quantum requirement for carbon dioxide would be only one-fourth of the requirement for oxygen.

Conclusion

It follows from the data obtained[1] that in the spectral region 630 to 660 mμ no more than 4 quanta are required to produce one molecule of oxygen gas. A requirement of 3 quanta is open to serious consideration, although thus far the average value in our experiments has been nearer 4 than 3.

A quantum requirement of 4 means that the efficiency of the energy transformation in our experiments was approximately $\frac{112{,}000 \times 100}{4 \times 44{,}000} = 65$ percent, whereas the quantum number 3 would mean an efficiency of about 85 percent.

In any event, under favorable conditions the greater part of absorbed light energy can be transformed in green cells into chemical energy, and this is, to quote the man who laid the foundation of quantitative photochemistry, "a marvellous achievement of nature" (*2*).

[1] Reported in greater experimental detail in *Biochem. et Biophys. Acta*, October 1949 (Meyerhof-Festschrift volume); *Arch. Biochem.*, September 1949; and at meeting of Society of General Physiology, Woods Hole, Massachusetts, June 1949.

Addendum

Quantum requirement determinations were demonstrated to, and carried out with the aid of, the students of the physiology class at the Woods Hole Marine Biological Laboratory on July 19 and 20. Requirements of 3 to 5 quanta per molecule of oxygen gas produced in photosynthesis were observed on these two days. The respiration was overcompensated several fold by light of unmeasured intensity from an incandescent lamp used with or without red filter (cut-off at ≦ 560 mμ). In two closely comparable, consecutive experiments, quantum requirements of 3.0 and 3.5 were obtained from measured red light (630–660 mμ) when the overcompensating light entered the manometric vessel as, respectively, white light from above and filtered red light from below. In the latter instance the cells mainly responsible for overcompensation by unmeasured light were identical at any given moment with those receiving the added measured red light. The absorbed measured red light was but a fraction of the total energy flux absorbed, most of which was absorbed in the first millimeter of depth. The aid of students Jack Durell, Richard Klein, Burlyn Michel, and Martin Schwartz in carrying out various of the class experiments is acknowledged gratefully.

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Scientific and Industrial Research in Britain

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THE PROBLEM of government help for science in industry is to secure the advice of both science and industry on what is needed, and then to combine reasonable continuity with some broad measure of democratic control. Like other problems of organization which are a little out of the ordinary, it has been handed in Britain to the Privy Council.

This is a centuries-old body which derives its authority directly from the King, and so carries weight; and as it is a purely formal body with no well-defined terms of reference it can conveniently concern itself with this problem. It is the Privy Council which nominally runs Britain's Department of Scientific and Industrial Research for the King. But the £4,199,625 which is the department's estimated expenditure for 1949–50 is provided in the normal way by Parliamentary vote, and the Lord President of the Council, chief of the Privy Council, is a cabinet minister. The advantage of the Privy Council connection is that it provides an administrative umbrella for an advisory council which is genuinely active. This consists of a mixture of outside scientists and industrialists, particularly those connected with industrial research, with two trade unionists as a more recent addition. The secretary of this advisory council is the permanent head of the department—at the present time Sir Ben Lockspeiser.

Of the department's staff of 3,200, more than 1,900 are engaged in research or technical work, including the supply of information. The department has twelve research stations of its own, supports some forty cooperative research associations, which among them cover the greater part of British industry, and by a system of grants encourages what it considers promising research at universities. Finally, through its headquarters, the department aims to act as a general clearing house for the exchange of scientific information of interest to industry; and with the same object, research associations are being encouraged to provide sufficient outside staff to bring information, and the means for information, directly to individual firms. No one and no organization can be omniscient, but an efficient information service can and should know where up-to-date information is to be found—whether in print or from someone who knows.

Gaps in Research

The main job of a research department is to fill gaps in research. Such gaps may be of different kinds and arise for different reasons. One is where the cost and size of certain equipment are greater than could be afforded without the help of the department. This is true of the wind tunnels used for the study of airflow and the design of aircraft, and the two 650-foot ship tanks at the National Physical Laboratory, Teddington, London. Both are competitively necessary for the industries they serve, not only for testing particular designs, but even more for the building up of a secure foundation of knowledge on which advances in design can be based.

The National Physical Laboratory is also responsible for maintaining national standards of length, weight, and so on. This is not research in the ordinary sense, but it involves research, and is of direct importance to industry, for in the long run all accurate measurements of whatever kind go back to laboratory standards.

A second kind of gap is where the demand for improvement comes from the user, rather than from manufacturer or producer. An example is the work of the chemical research laboratory of Britain's Department of Scientific and Industrial Research on the corrosion of metals. The laboratory is at the present time studying the thin surface films which give metals protection, and its work on the corrosion of iron pipes by bacteria in certain types of soil may well repay the running costs of the laboratory for all time. The chief users in this case are water supply undertakings, for the most important buried pipes are water mains.

In the case of noise, the user is anyone whose home is in a block of flats. This problem is a special case of the replacement of traditional methods of building by others less extravagant in time and materials, and the basic research on accoustics is undertaken at the National Physical Laboratory.

Food Refrigeration

Research on the storage and transport of food is also in the ultimate interest of the British public as eaters of the food. The older side of the department's work was on low temperature storage, and its prin-

cipal laboratories were at Cambridge, Aberdeen (for fish), and at East Malling in southeast England (for fruit). Examples of practical achievement have been the refrigerated gas storage of fruit and meat. A pest infestation laboratory was established in 1939, at a time when the government was much concerned over the wartime conservation of the nation's food stocks, chiefly grain. Since it is now a world, as well as a national, problem to obtain the best use from available food resources, it is probable that work on these lines will continue permanently.

The Forest Products Research Laboratory at Princes Risborough, near London, is used by interests in Britain, although it works closely, too, with the forestry departments of overseas territories on the suitability of particular timbers for various uses. It is concerned with the seasoning and preservation of timbers, as well as with their properties, and its work has been considerably increased by the wide use recently of substitute timbers.

The Building Research Station at Watford, near London, has played a large part in British postwar housing plans by working out standards of construction and methods of testing. It is a "user" laboratory, in the sense that neither individual local authorities nor small builders could be expected to carry out the necessary research if left to themselves, and it is directly in the interests of the householder that this research should be carried out.

Fuel and Radio Research

A third category of research is that directed to the best use of any national asset too important to be left to take its chance. The outstanding example in Britain is that of coal—and this brings in the Geological Survey, in the finding of coal and the collection of samples for examination; the Fuel Research Station at Greenwich, London, on the properties of different coals and their efficient use; and the Building Research Station, on domestic heating.

Other laboratories, which have not been mentioned, deal with road research and river pollution. Radio, and particularly radio propagation, is an old interest in the department which has already paid dividends in the development of radar and the use of radio methods in weather forecasting. Radio research, generally, is at present divided between the National Physical Laboratory and a small subsidiary station near Slough, outside London. A site is being sought for a new station at which the department's radio work can be centralized. A second new station, for work on mechanical engineering, is already being built at East Kilbride, near Glasgow, and a third for work on river and harbor models will be built when a suitable site is found.

All these activities are designed to close gaps which, it is felt, can be best closed by government action. And the search for such gaps continues. At the present time a committee is considering needs for research in chemical engineering. Finally, it may again be emphasized that all these institutions are centers of information as well as of research. They are collections of experts as well as of machines and equipment. And they are at the service of other government departments, cooperative research associations, and individual private firms which may have problems to present, with the intelligence division of headquarters as a general signposting unit.

TECHNICAL PAPERS

Qualitative Differences of Malignant Tissue

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Recently, Carruthers and Suntzeff (*2*, *3*) have published two important papers. Based on polarographic investigations, they conclude that, in opposition to the current view, certain tumor lipids show qualitative[1] differences from those in normal tissues. These lipids seem to arise at the moment of carcinogenesis, for in the preparative stages no differences are observed. They are soluble in alcohol-ether mixtures; probably they are bound to proteins.

We would like to draw attention to the fact that, long ago, several immunologists (the field of cancer immunology seems to be somewhat neglected in recent years) showed that there exists a true tumor antigen of lipid character, which is able to incite the formation of specific antibodies in the rabbit, though only in a few animals (Hirzfeld and his school—1931 *et seq.*).

We will also refer to the early paper by Waterman and de Kromme (*6*) (1929) wherein it was shown that iso-

[1] In a nature-philosophical sense there exist, of course, no qualitative differences, since all matter is built up from the same element in varied distribution.

lated suspended tumor cells are agglutinated by the sera of animals, not belonging to the Forssman group on account of their containing a specific antigen, but probably related to the heterogenetic Forssman antigen. De Kromme (*4*) has prepared specific antisera by injecting rabbits with carefully washed tumor cells; these antisera react with a precipitation reaction with the lipid tumor antigen excreted with the urine. This observation has been made the base of a diagnostic reaction in the first specific ethers of cholesterol.

As to the chemical nature of the antigen, Kolodziejska and Halber (*5*) and Breinl and Chrobok (*1*) have investigated this by means of complement-fixating tests with the sera of immunized rabbits. Kolodziejska and Halber assume that fatty substances are the specific substance, or that in any case the specific substance is carried with the fatty acids. Breinl and Chrobok locate the antigen in specific ethers of cholesterol.

In the last few years we have renewed our attempts at isolation of this antigen. An example of our recent procedure is offered here. We must confess, however, that so far we have not been able to isolate a substance with a well defined melting point, although we have arrived at a fraction, of which 0.1 μg reacts promptly with precipitation in the form of a ring test when brought in contact with the immune serum.

Perhaps the communication of our procedure may help other investigators to define the nature of the lipid. If so, we believe that an important piece of work will have been performed. In any case, the agreement of polarographic investigations with serological results would be very gratifying.

Case II. Over a period of a week 1100 g of metastatic liver tumor (carcinoma mammae) is extracted with 11 l alcohol, 96% acidified with 10 cc HCl 7 N at 37° C, under frequent stirring.

After filtration, the alcohol is distilled off and the watery residue (*plm.* 1 l) is extracted during 48 hr with a 50% mixture of ether and petrol-ether. The ethereal extract is evaporated to 150 cc and brought to 1 l with acetone. The precipitated phospholipids are filtered off, and the yellow filtrate is evaporated *in vacuo*. The resulting brown oily residue is stirred with 1 l 1% natrium carbonate (pH 9.5). This yellow soap is extracted during 48 hr with ether. The watery solution is brought to pH 3 with 30 cc HCl 25% and the acid solution is extracted again with ether. This ethereal extract is brown.

After evaporating off the ether in nitrogen atmosphere, there remains 8.5 g of a dark brown oil. This is solved in 800 cc alcohol 96% at 70° C. To this solution a boiling clear solution of 5 g lead acetate in alcohol is added; the lead salts of the higher saturated fatty acids are precipitated. After 12 hr standing, these are filtered off on a Büchner funnel. A stream of H_2S is conducted into the clear yellow filtrate containing the soluble lead salts, and the lead sulfide is removed. After evaporation of the yellow filtrate in nitrogen atmosphere the resulting red-brown oil is suspended in 800 cc 12½% ammonia under heating to 80° C. After standing overnight, the ammonia is removed by a stream of nitrogen.

After adding 8 g of barium chloride an orange precipitate is formed, which is washed with water. The precipitate is solved in 80 cc 10% HCl and extracted again with ether. After evaporation (residue: 4½ g) the extract is solved in petrol ether (40–60° C) in order to remove any hydroxy-acids that may be present, and filtered. The solution is agitated with water, dried again, and dissolved in 50 cc dry acetone. The insoluble fraction is filtered off and washed with cold acetone. The brown acetonic solution is cooled for ½ hr at −20° C and the precipitate is rapidly centrifuged in cooled tubes. The precipitate (130 mg) proves highly active in the immunological test (ring reaction with cancer immune serum).

The same treatment is repeated. The rose-colored precipitate is solid at room temperature (26 mg). It is soluble in warm, dry, alcohol-free ethyl acetate: by cooling at 6° C and centrifuging a white precipitate is formed; the ethyl acetate is yellow.

This treatment is repeated four times; now the filtrate is colorless. The precipitate is dried *in vacuo* and becomes slightly brownish thereby. Melting point 100–130° C.

The treatment with barium chloride is repeated, followed by the ethyl acetate procedure described. The resulting precipitate is highly active. One-tenth μg is active in a concentration of 1: 1,500,000.

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A One- and Two-dimensional Paper-Partition Chromatographic Apparatus

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The ascending force of capillary action for chromatographic separation, reported earlier by Williams and Kirby (*1*), has been used in the apparatus to be described here. The apparatus (Fig. 1) consists of a 1-liter graduated cylinder, a No. 13 rubber stopper, some adhesive cellophane tape, and a stainless steel paper holder constructed from two flat and open coils, 60 mm in diameter, and two rods or tubes, 340 and 400 mm in length. Each of the two coils is made from a piece of stainless steel wire or tubing 432 mm in length and 2 mm in diameter. Both ends of the piece of wire or tubing are flattened and fashioned into loops. The longer rod is passed through

the inner loop of the lower coil and is permanently attached to it vertically at a point 25 mm from the lower end. The shorter rod is permanently attached at one end of the outer loop of the lower coil so as to be parallel to

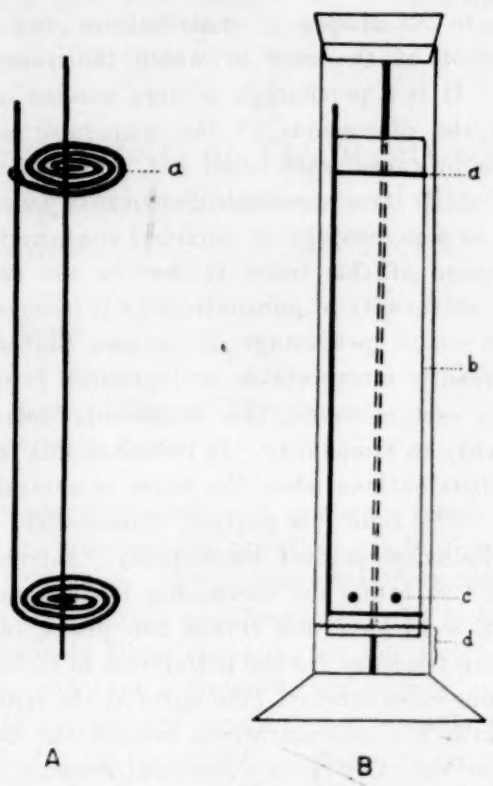

FIG. 1. Chromatographic apparatus. A—Paper holder with adjustable coil (a). B—Assembled apparatus, showing adjustable coil (a), paper (b), position of test spots (c), and liquid volume (d).

the other rod. The two rods are passed through the corresponding loops of the upper coil but are not fastened to them. Since the upper coil can be raised or lowered, it is possible to use sheets of paper of different size, up to 350 mm square. A paper sheet is loaded conveniently by threading it through the coils with a gentle rolling motion.

Chromatograms are usually run on sheets of filter paper 300 to 330 mm long and 230 to 280 mm wide. For one-dimension chromatograms, both the standard and unknown solutions are pipetted onto the paper at a distance of 25 mm from the bottom of the sheet. The liquid usually covers an area 3–5 mm in diameter. After the spots have dried, the paper is rolled into the paper holder. The paper should extend about 10 mm below the lower coil and about 25 mm above the upper coil. The loaded paper holder is quickly placed in a 1-liter cylinder, containing 100 ml or less of solvent, with about 10 mm of the lower edge of the paper in the solvent. The cylinder is closed with the rubber stopper and if it has a lip the hole is sealed with adhesive cellophane tape. The liquid is allowed to ascend by capillary action for a fixed period of time. After expiration of the allotted time, the chromatogram is removed from the cylinder and dried in a stretched horizontal position and then analyzed according to the particular method in use.

For a two-dimension chromatogram, a single spot of test solution is placed in the lower left corner of the sheet of paper, approximately 50 mm from the edges, and the sheet is then placed in the paper holder and treated as described. After expiration of the allotted time, the chromatogram is dried. The sheet is then placed in the paper holder in such a manner that the separated constituents are made to travel upward along the paper at a right angle to the direction from which they moved previously. The final chromatogram is removed, dried, and analyzed.

This apparatus has a number of advantages. It is simple in design, requires small space, and is airtight. The chamber can easily be protected from light if the compounds are light sensitive and construction can be all-glass if conditions demand.

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Note on an Index of Conformity

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An index to measure the degree of conformity to some norm, or single class interval, of a variable is here proposed. It is an improvement in percentage form of the 4th moment (in sigma units) or Pearson's beta sub-two (taken from an arbitrary origin), which Peters proposed under the label of an "index of institutionalization" (*1*). This index had grown out of studies such as those by Allport on the "J curve of conforming behavior." The formulas for our "index of conformity" (Cfy) and graphs of its behavior are given in Fig. 1. Its derivation is simply that, since the 4th moment varies from unity to infinity, its reciprocal will vary between the limits of 1 to 0. This measures nonconformity so that the complement from unity of this reciprocal is taken to measure degree of conformity. This proportion is multiplied by 100 to express it in familiar percentage units. The origin about which the moment is calculated is the norm or class interval of expected behavior, i.e., any arbitrary origin to which the degree of conformity of the data is to be tested.[1]

$$\text{Cfy} = 100(1 - (\Sigma x^2)^2/N\Sigma x^4)$$

where $x = X - \text{norm}$.

This index measures the degree of concentration in, or dispersion from, one class interval which may be the norm in the social mores, or may be any class interval set up by the analyst as an hypothesis for testing the degree of conformity of the data to it. It measures kurtosis on a scale where 100% is maximum, around 67% is mesokurtic, around 50% is platykurtic, and 0% is negatively

[1] At the limit of complete conformity, when all deviations from the norm are zero, beta sub-two becomes indeterminate, needing evaluation. Aside from the mathematics of this case, its computation gives no trouble, since conformity is evidently maximal and can be so recorded on mere inspection.

leptokurtic or maximal anticonformity.[2] In Fig. 1, the base lines correspond to the amount of conformity of each graph in the conformity scale (Cfy) at the left. Graphs

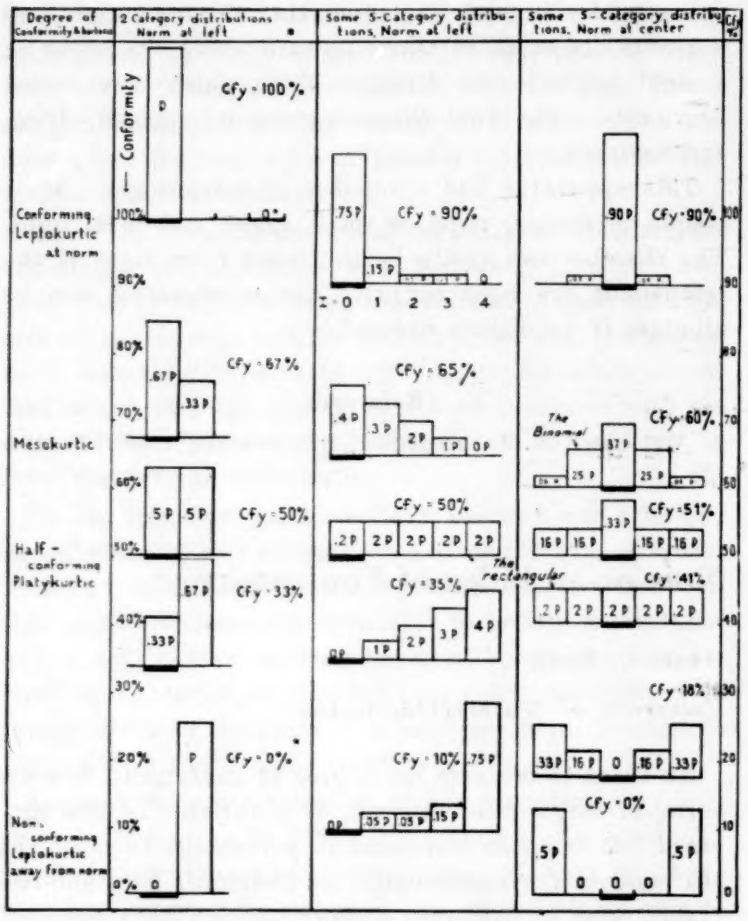

FIG. 1. Conformity distributions.

Conformity = Every person in the standard or norm class interval (underlined) which is expected by the mores. Cfy = 100%

Nonconformity = Every person furthest from the norm class interval (underlined) which is expected by the mores. Cfy = 0%

* It makes no difference whether many or no categories intervene in a two-category distribution.

are presented for the simple two-category cases of conforming or nonconforming in the first column, and for the case of five categories or class intervals of the variable in the second and third columns (which differ only in that the norm is at one extreme in the second column and is at the middle in the third column). The graphs show clearly for some common types of distributions how perfect conformity means that all the frequencies are in the norm class interval; around 50% conformity means a rectangular distribution in general, with the frequencies equally divided among all class intervals, and 0% conformity means that the frequencies are all concentrated in the class intervals furthest away from the norm. Further features of this index are seen to be that it is applicable to all shapes of distributions and that it is independent of the unit in which the variable is expressed. It is a percentage or pure number, since in its formula the dimensions of the numerator and of the denominator cancel each other out, leaving a dimensionless ratio. It thus measures conformity to a norm expressed as a percentage of maximal conformity. A further feature of this index is that in the two-category cases of conformity or nonconformity it becomes identical with the simple percentage of persons conforming, and thus is readily interpretable by laymen.

Within certain limits, this conformity index indicates unimodality to bimodality. It indicates this best in symmetric distributions when the norm is central. Then a Cfy of 100% indicates perfect unimodality; while Cfy of 0% indicates perfect biomodality. Intermediate degrees of Cfy, while not measuring the tendency for the distribution to have one versus two peaks, measure the underlying tendency for the population to be concentrated around one class interval (the norm at the center) or dispersed into two concentrations around the two extreme class intervals. Cfy is not a constant measure of bimodality, since the relation of Cfy to degree of bimodality will shift with the conditions. Thus, under conditions of an asymmetric distribution with the norm not central, 0% will not indicate perfect bimodality.

As the index drops it reflects a homogeneous or unified population, becoming separated into two opposite camps with respect to the characteristic measured. Cfy thus can measure the degree of enmity or opposition of two groups along a given dimension. Cfy does not measure the dichotomizing of a group into two camps under all conditions; rather it measures the conformity or absence of deviation of a group from a norm.

This index should have wide usage and great convenience in sociology, psychology, and other fields in measuring the degree of deviation from some expected behavior or conditions wherever that is one of two or more possible class intervals of such behavior or conditions. It can crucially test hypotheses.

For judgments of sampling reliability, one may use the standard error of the 4th moment, whether calculated about the mean or about an arbitrary origin. For large samples, this is the usual $\sigma^4\sqrt{96/N}$. Or one may use the standard error of beta sub-two about an arbitrary origin.

For an example of its use, Peters' data of automobile drivers keeping in their proper lanes on highway curves may be taken. His data are 85.3% in lane, 12.1% crossing less than half, 1.7% crossing more than half, 0.8% crossing fully into the other lane, giving an index of institutionalization of 15.3, which cannot be readily interpreted unless one has many such indices in mind to compare it with. The index of conformity for these data is 93.5%, which has immediate interpretation even to lay-

[2] The mesokurtic and platykurtic percentages will vary somewhat, depending on the shape of the distribution, the number of class intervals, and the location of the norm between the center and one end. Thus the mesokurtic normal probability curve with $B_2 = 3$ has an index of conformity of 67% when the norm is at the mode. For another example, the platykurtic rectangular distribution of five class intervals illustrated in Fig. 1 has a conformity index of 50% when the norm is at one end and 41% when the norm is the middle class interval. Cfy measures kurtosis strictly only when the norm is the mean.

men as being 93.5% of maximal or perfect conformity to the traffic regulations.

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Histological Effects of Treatments with Growth-regulating Substances of the 2,4-D Group[1]

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Recent anatomical studies of the bean plant (*2*) and nut grass (*1*) treated with growth-regulating substances of the 2,4-D group (2,4-dichlorophenoxyacetate) have shown that the internal modifications in the monocot are closely similar to those occurring in the dicotyledonous bean plant; and that a monocot, which from superficial study might be reported insensitive or slightly sensitive because of little or no external evidence of effect of the treatment, may be seriously affected in internal structure. Because of difference in method of growth in dicots and monocots the histological modifications naturally vary somewhat in the two plants in type and in position in the plant body, and the external form of the affected organs is modified in different ways. In monocots, external structural effects are commonly less evident than in dicots and may not be at all apparent if the plant dies soon after treatment. Detailed descriptions and photomicrographs of the anatomical modifications of the two plants under treatment are in the papers listed in the references.

In both plants, the modifications occur in immature tissues, as has long been recognized, or in tissues that, though mature, become readily meristematic, especially the pericycle and endodermis. Under both types of growth, primary phloem is distorted or destroyed. In the nut grass, the phloem of the vascular bundles in the growing leaf bases does not form or is destroyed as replacement tissue forms. The xylem is also distorted and its cells filled with gummy substances. The mature vascular bundles in the corm are uninjured. In the bean leaf also, the phloem is distorted or destroyed, and in the young bean stem the primary phloem is destroyed and no secondary phloem forms.

In addition to vascular distortion and reduction, two general types of modification occur: (1) That in which the course of cell and tissue development is so changed that the normal cells and tissues of the region are supplanted by a special type of fleshy parenchyma—with cells proportionately large, more or less irregular in form, strongly vacuolate, without chloroplasts, and with few or no intercellular spaces (Fig. 1B, D). This tissue is suitably called replacement tissue. (2) That in which the response is one of rapid and continuing proliferation of a layer or layers of cells somewhat similar to that of cambial activity (Fig. 2B, D), producing uniform, thin-walled parenchyma cells, some of which become richly cytoplasmic, closely resembling promeristem cells, and give rise to root initials. Proliferation from both vascular and nonvascular tissues is frequent in the young bean plant, with the new tissues arising chiefly from vascular derivatives. In the monocot stem, where there is no cambium, only pericyclic (and to a small extent endodermal) tissue takes part in the formation of new tissue. Proliferation in the stele may extend outward along the leaf traces.

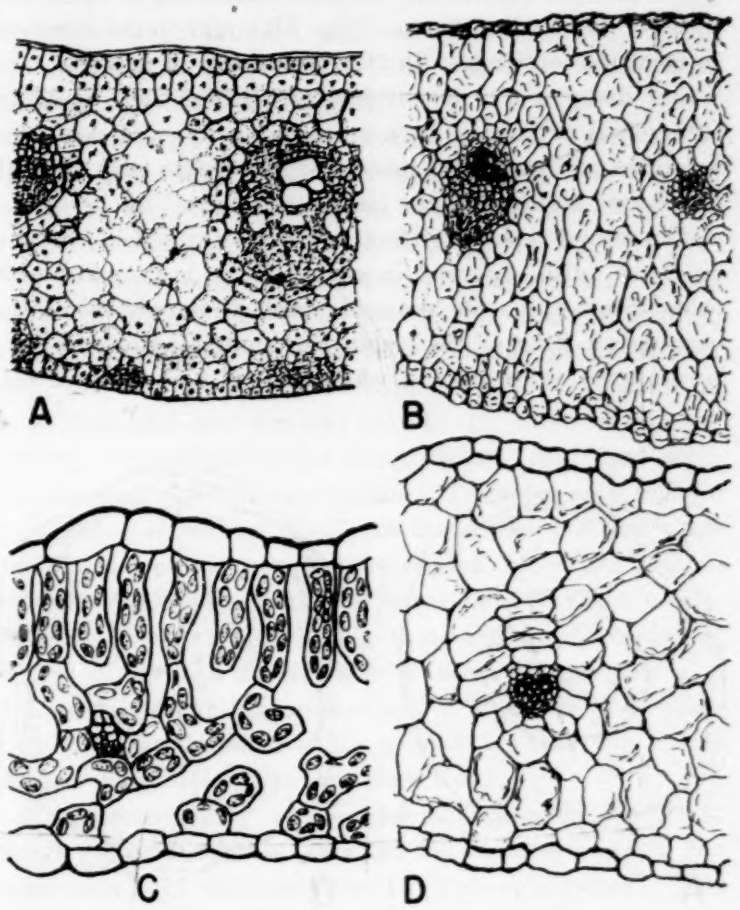

FIG. 1. Transverse sections of portions of normal and treated leaves of nut grass and bean plant. The treated leaves of both plants show increased thickness, replacement tissue, and abortive vascular bundles. A,B, nut grass: A, normal leaf nearing maturity, showing beginnings of differentiation of epidermis, mesophyll, vascular bundles, fiber strands, and aerenchyma; cells with much cytoplasm and conspicuous nuclei. B, treated leaf of about the same stage of maturity as A, lacking normal differentiation of tissues, showing replacement tissue with cells strongly vacuolate and cytoplasm scanty; the vascular bundles reduced and distorted. C, D, bean plant: C, normal mature leaf showing differentiation into epidermis, mesophyll, and small vascular bundle; mesophyll with abundant chloroplasts. D, mature treated leaf showing replacement tissue with cells strongly vacuolate, without chloroplasts: cytoplasm scanty; vascular bundle distorted.

[1] This paper is based upon work done for the Biological Department, Chemical Corps, Camp Detrick, Frederick, Maryland, under Contract No. W-18-035-CM-168 with Cornell University.

The first type of response (replacement tissue formation) takes place in the leaves and morphologically similar organs; here increase in thickness is minor. In the dicot, conspicuous distortion of external form is soon evident—extreme narrowing of the leaf blade caused by persistence of apical initials and inhibition of development of interveinal tissue (Fig. 3B) with some increase in thickness of blade. In the narrow-leaved monocot, external distortion is inconspicuous because there is little interveinal expansion in normal ontogeny, and with development from a basal intercalary meristem only a basal transverse segment of the leaf is affected (Fig. 3A).

The second type (proliferation tissue formation) occurs in stems (also observed in roots of the bean plant and other dicots and some monocots) and commonly results in extreme swelling of the organ with compression and rupture of the outer tissues, which do not take part in the proliferation. The cortex apparently is little or not at all affected.

Growth of replacement tissue to maturity is complete in a short time, about the same as in normal development; growth of proliferating tissue may continue for a long time. The same stimulus, however, produces both types of response, and is immediate and brief; there is no later stimulus without further treatment. The stimulus of 2,4-D treatments has been reported to be long-continuing in many plants, but these studies indicate that the reports are based on false interpretation of the evidence. Although the stimulus is immediate and brief, dormancy of some plants after treatment may delay the development of the affected immature tissues or organs (especially buds in woody plants and embryos in seeds) and external evidence of the injury is thus concealed until growth is renewed. Evidence of injury appearing in the spring following treatment is frequent in many plants.

From the anatomical study of this monocot and dicot it is clear that, although injury in the bean plant is far more conspicuous externally than in the nut grass (Fig. 3) because of the difference in method of growth, the modifications in both monocot and dicot are fundamentally the same (Fig. 1B, D; Fig. 2B, D).

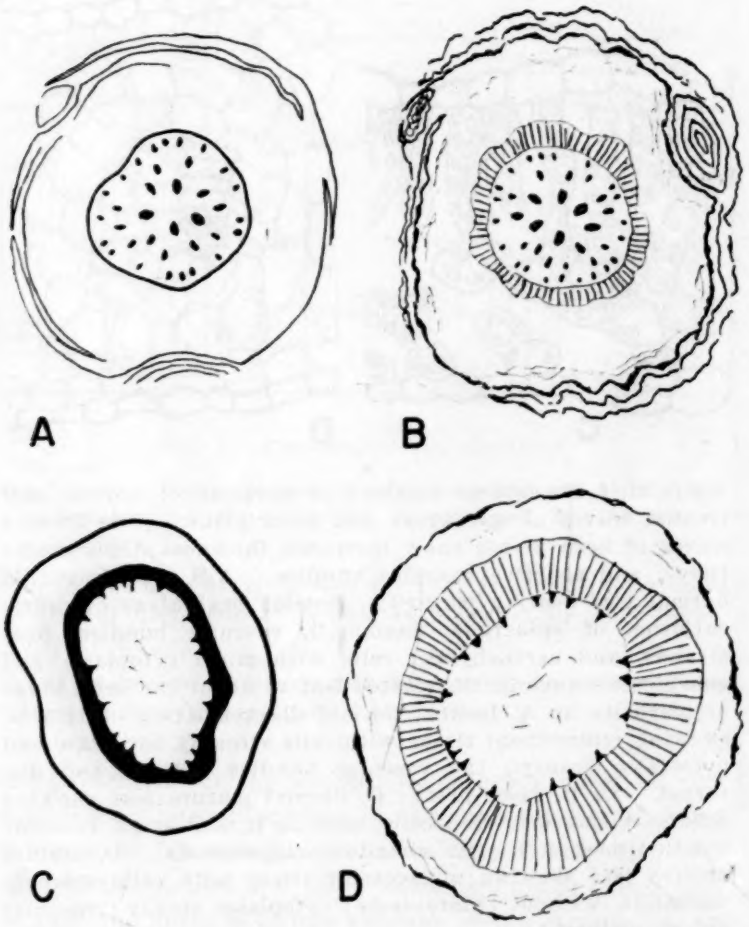

FIG. 2. Cross sectional diagrams of fairly mature corms of nut grass and young stems of the bean plant. A, B, nut grass: A, normal corm showing vascular bundles (black) in the central cylinder surrounded by the pericycle and endodermis (indicated by circle) and cortex with leaf bases and young rhizome tip; B, treated corm showing vascular bundles in the central cylinder as in the normal corm, proliferation of pericycle and endodermis (indicated by the lined area), the cortex somewhat crushed and torn, the epidermis ruptured, and the surrounding leaf bases shrunken. C, D, bean plant: C, normal stem showing vascular cylinder in black with points of protoxylem extending into the pith; D, treated stem showing pith and protoxylem as in the normal stem, proliferating tissue (indicated by the lined area) produced chiefly by the cambium and its derivatives in place of normal secondary vascular tissue, the cortex somewhat crushed and torn, and the epidermis ruptured.

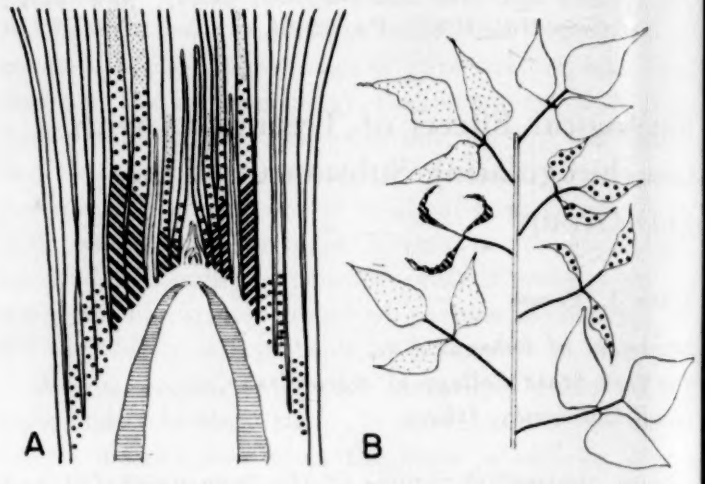

FIG. 3. Extent and distribution of injury in leaves of treated monocot and dicot. Hatching indicates regions of worst injury; large dots, regions of less severe injury; stippling, regions of least injury; and white areas, normal parts. A, diagram of median longtitudinal section of tip of corm and base of leaf fascicle of nut grass showing youngest and oldest leaves unaffected and between these the affected ones (immature at time of treatment). The leaf injury is externally inconspicuous because it occurs only in the basal portion of the leaf. In the worst-affected leaves, all three types of injury occur in one leaf. (Horizontally lined area in the corm indicates the proliferated tissue.) B, trifoliolate leaves of bean plant showing youngest and oldest unaffected, and varying degrees of injury in leaves between the unaffected ones. The injury in the bean plant is conspicuous because the whole leaf is distorted and an entire leaf usually shows one type of injury. (A, after Eames, modified; B, after Watson, modified).

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Increased Permeability of the Hemoencephalic Barrier Produced by Physostigmine and Acetylcholine[1]

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Barbour and Abel (*1*) observed that acid fuchsin, when injected into the lymph sac of frogs, caused tetanic convulsions, but that there was generally a marked delay (often 24 hr) before the onset of the convulsions. These observers believe that the delay was caused by the slow rate of absorption of the dye by nervous tissue. They then removed the cord, treated it with acid, and observed the degree of staining of the cord. The time of onset and the degree of convulsions paralleled the amount of dye in the cord.

TABLE 1

EFFECT OF PHYSOSTIGMINE AND ACETYLCHOLINE ON THE RATE OF ONSET OF CONVULSIONS IN FROGS PRODUCED BY ACID FUCHSIN

Group	I Acid fuchsin	II Physostigmine + acetylcholine	III Acid fuchsin + physostigmine + acetylcholine
Number of frogs	19	23	26
Number that did not have convulsions ...	5	23*	4
Number that had convulsions in less than 1 hr	4	0	22
Number that had convulsions in a period longer than 1 hr ...	10	0	0
Average time for convulsions to occur ...	12.6 hr		34 min
Range of times for convulsions to occur ...	41 min–26 hr		18 min–49 min

* Four frogs in this group died without evidence of convulsions.

In our work on factors affecting the permeability of dog erythrocytes it was found that a disturbance of the acetylcholine-cholinesterase system affected the permeability (*2*), and it was felt that a simple method of determining whether other cells were also affected might be found by studying the effect of physostigmine, a specific inhibitor of cholinesterase, and acetylcholine on the rate of passage of dye through the hemoencephalic barrier as indicated by the degree of staining of the cords of frogs treated with physostigmine, acetylcholine, and acid fuchsin and the time of onset of convulsions.

The drugs were injected into the dorsal lymph sacs of the frogs in the following quantities: acid fuchsin 5 mg, acetylcholine bromide 1 mg, and physostigmine 0.1 mg for each 5 g of body weight. The time when convulsions occurred was then determined.

Experimental results are summarized in Table 1. It may be seen that of the 19 frogs receiving acid fuchsin alone, 14 went into convulsions and the average time for the onset of convulsions in these frogs was 12.6 hr. Of the 26 frogs receiving acid fuchsin, physostigmine, and acetylcholine, 22 went into convulsions, and the average time for the onset of convulsions in this group was 34 min. In this group if the frogs did not convulse in an hour they did not convulse at all. Of the 23 frogs receiving physostigmine and acetylcholine, four died without showing signs of convulsions. Tests for acid fuchsin in nervous tissue by Abel's method were positive when the frogs were in convulsions caused by physostigmine and the dye, and negative if convulsions had not begun. We also observed, as did Abel, that the frog's eye became deeply pigmented at the time of onset of convulsions.

On applying the chi-square test of significance to these results it was found that the probability that this was a chance distribution was less than 0.001.

The permeability of the hemoencephalic barrier of frogs to acid fuchsin appears to be increased by the inhibition of cholinesterase by physostigmine. This change in permeability is similar to that found in dog erythrocytes treated with physostigmine. The acetylcholine-cholinesterase system may have a widespread function in maintaining the normal permeability of the living cell.

[1] Funds for carrying on this work were kindly supplied by the Mallinckrodt Chemical Works.

[2] U. S. Public Health Fellow of the National Institutes of Health.

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Dispersion Staining with Phase Contrast Microscope Accessories. The Microscopic Identification of Quartz

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Results similar to the transmitted light bright field Christiansen effect (*1*) and the dark field dispersion staining method (*2–6*) can be obtained with chemicals and minerals by means of phase contrast microscope accessories. The colors obtained with phase objectives as compared to non-phase are much more vivid—brilliant enough to produce good color transparencies. A further advantage is that they can be observed best at focus rather than above or below a good focus, a necessary condition with non-phase objectives. As compared to the

dark field method, the colors are not quite as brilliant and are observed best at the lower magnifications, such as with the 10× (16-mm) 0.25 N.A. and 21× (8-mm) 0.50 N.A. objectives. Weak coloration can very often be obtained with the 43× (4-mm) 0.65 N.A. objective. This is especially true when using the higher index liquids which, containing a greater proportion of cinnamaldehyde, have a higher dispersion. The use of high dispersion liquids as mounting media with the phase microscope offers the advantage that the end point in the determination of refractive index by color is probably easier to obtain than by dark field illumination. Critical numerical aperture relationships between condensers and objectives necessary in the dark field method are not required. When the method is used in conjunction with polarized light, more than one identifying color can be obtained, dependent on the orientation of the specimen. Particles not readily visible at one optical orientation can often be reorientated so they stand out in sharp contrast to the mounting medium. The method can be illustrated best by the directions given below for the identification of quartz, N_w 1.544 and N_e 1.553.

Particles, crushed to a smaller size if necessary, should be mounted under a cover glass in a liquid of high dispersion and of a refractive index of n_D 1.544 at 25° C prepared from a mixture of diethylene glycol monobutyl ether and cinnamaldehyde (Eastman Kodak Company). The quantity of the lower index constituent, to be mixed with the higher to give an index of 1.544 at 25° C, can be determined by the formula

$$V_1 n_1 + V_2 n_2 = V_x n_x$$

where V represents volume, n the index, and $V_x n_x$ the volume and index desired. Our samples of diethylene glycol monobutyl ether had an index of 1.429 and cinnamaldehyde 1.619, both readings being taken at 25° C. A 1.544 index liquid would require a mixture of 3.95 cc of diethylene glycol monobutyl ether with 6.05 of cinnamaldehyde, as shown in the computation given below:

$$1.429V_1 + 1.619V_2 = 10 \ (1.544)$$
$$1.429V_1 + 1.429V_2 = 10 \ (1.429)$$
$$.190V_2 = 1.15$$
$$V_2 = 6.05 \text{ cc}$$
$$V_1 = 3.95 \text{ cc}.$$

For more accurate results, the mixture prepared according to the above formula should be checked on a refractometer at 25° C. It is also advisable to recheck its index occasionally for any change, since cinnamaldehyde tends to oxidize to cinnamic acid. This shift in index can be retarded by keeping the index liquid in a small bottle and maintaining it nearly full of the mixture. Other index liquid combinations can be used, but the colors obtained will tend to be less vivid.

The results given here were obtained with dark contrast phase objectives having phase accelerating annuli of one-quarter wavelength. Critical illumination should be employed and the condenser diaphragm image and phase accelerating annulus accurately centered. A microscope illuminator having a 6-v 108-w ribbon filament lamp and daylight filter was used as a light source. Preparations mounted in the 1.544 index liquid were examined at a temperature of 25° C by means of the 10× (16-mm) 0.25 N.A. and 21× (8-mm) 0.50 N.A. objectives. Observations were made with nonpolarized light and with polarized light obtained by placing a cap analyzer over the microscope eyepiece. Grains of quartz with nonpolarized light at 25° C appear colored blue with orange. With polarized light (cap analyzer over eyepiece) grains oriented for the 1.544 index are colored blue with red, and those oriented for the 1.553 index are blue with yellow. Any inclusions or particles on the surface appear white or in colors other than those characteristic for quartz. As an additional means of identification, grains can be examined in a 1.553 (epsilon index for quartz) index liquid prepared in a similar manner at 25° C from diethylene glycol monobutyl ether and cinnamaldehyde. Quartz grains in this liquid with nonpolarized light at 25° C appear light blue, usually with a very dark red border. With polarized light (cap analyzer over the eyepiece) grains oriented for the 1.553 index are colored blue with red and those for the 1.544 index a light blue to white. The red, orange, and yellow colors are usually in the form of colored borders to the grain but occasionally, depending on its shape, can be found at any point in the particle. The blue colors always cover the major portion of the grain and vary in hue from light to dark blue, depending on whether the grain is below, equal to, or above the index liquid. This criterion in conjunction with the red, orange, and yellow coloration is of additional value in determining the grain-index relationship.

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3. ———. *Anal. Chem.*, 1948, **20**, 976.
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Book Reviews

Introduction to historical geology. Raymond Cecil Moore. New York-London: McGraw-Hill, 1949. Pp. ix + 582. (Illustrated.) $5.00.

This new book bids fair to become one of the leading textbooks in the country for beginning college courses. It is an authoritative treatment of historical geology by a leading student of stratigraphy and paleontology, and a teacher of more than thirty years' experience.

The facts of historical geology are presented concisely and clearly, by means of lucid text, large and beautiful illustrations, diagrams, correlation tables, areal and paleogeographic maps on facing pages, and many figures of fossils and restorations of landscapes and both vertebrate and invertebrate animals.

The book is well suited to beginning classes in geology, and the correlation tables and areal and paleogeographic maps make it useful for more advanced students of the stratigraphy of North America. Students use their texts in historical geology in identifying the fossils they collect on geological excursions. It would be better, the reviewer thinks, if the names of species had been given so that the figures could be used for specific as well as for generic identification.

Dr. Moore's book is fully equal, in the reviewer's estimation, to any textbook in historical geology now being used in this country. It is logically written, adequately illustrated, and is authoritative, accurate and up to date.

J. J. GALLOWAY

Indiana University

Elastomers and plastomers: their chemistry, physics and technology. (Vol. III.) ***Testing and analysis; tabulation of properties.*** R. Houwink. (Ed.) New York: Elsevier Publ., 1948. Pp. 174. (Illustrated.) $4.50.

This third volume of the series edited by Hermans, Houwink, and Martin is essentially devoted to methods of analysis and testing and to a presentation of numerical data on the mechanical, electrical, optical, and thermal properties of high polymers. This is a very important subject and a book on it is a welcome addition to the scientific literature in this field.

J. H. Teeple describes in about sixty pages the modern methods of plastics and rubber testing in a comprehensive, clear, and up-to-date manner, using a large number of well-selected figures and tables. A. G. Epprecht follows with a chapter on chemical analysis, which will be particularly interesting for American readers because it contains many European methods which are not as yet too well known in this country. A chapter by B. B. S. T. Boonstra on properties of elastomers gives additional information on these important materials, and the fifth chapter of J. W. F. Van't Wout and R. Houwink completes the volume by discussing the properties of plastics.

It is evident that books of this character are very valuable and necessary for chemists and physicists interested in this rapidly expanding field, and Dr. Houwink's series is contributing a great deal to the dissemination of factual knowledge and current ideas.

H. MARK

Polytechnic Institute of Brooklyn

Foundations of nuclear physics: facsimiles of thirteen original studies. Robert T. Beyer. (Ed.) New York 19, N. Y.: Dover Publ., 1949. Pp. 272. (Illustrated.) $2.95.

The use of original papers as a teaching device has been recognized in the natural sciences ever since Wilhelm Ostwald first reprinted a series of classics in the natural sciences. However, most of these papers were concerned with developments in days gone by, and only a few volumes in this series (in German) are devoted to modern developments (such as the volume on Brownian motion, which contains the famous papers by Einstein and Smoluchowski). The present volume presents a particularly interesting collection of thirteen of the fundamental studies in nuclear physics as they were originally reported in scientific journals. Everybody will agree with Professor Beyer as to the importance of the various papers. All of them had a profound influence on the development of nuclear physics and they cover a wide range of interests, from simple experimental descriptions to some rather difficult theoretical developments such as, for instance, Fermi's theory of β-decay and the theory of the interaction of elementary particles by Yukawa.

Of the classical papers on radioactivity, Rutherford's papers on the scattering of alpha particles and on artificial nuclear disintegration are included. The other papers are of the period when modern techniques made the discovery of new particles possible and wave mechanics gave the interpretation of their interaction with matter.

One may regret that Fermi's detailed paper from the *Proceedings of the Royal Society* has not been reprinted; also that the paper of the Joliots in the *Journal de Physique* has not been given instead of the short note in *Comptes Rendus*. We hope that a future edition will contain the brief note by Frisch and Meitner on fission. For the sake of the student one might wish that papers were accompanied by a commentary, because the beginner will find it necessary to have proper guidance if he wants to study this material by himself.

The bibliography, which covers such chapters as isotopes and mass measurements, hyperfine structures, nuclear moments and spin, scattering and collision processes, disintegration processes, radioactivity, beta radiation, gamma radiation and neutrons, the theory of nuclear structure, theory of disintegration processes,

nuclear fission, and finally a chapter on methods and apparatus, will be useful to the beginner as well as the research worker and teacher who wants a handy classified list of sources.

KARL LARK-HOROVITZ

Purdue University

Advances in catalysis and related subjects. W. G. Frankenburg, V. I. Komarewsky, and E. K. Rideal. (Eds.) New York: Academic Press, 1948. Pp. viii + 321. (Illustrated.) $7.80.

This book is a collection of the following eight articles: "The Heterogeneity of Catalyst Surfaces for Chemisorption," by Hugh S. Taylor; "Alkylation of Isoparaffins," by V. N. Ipatieff and Louis Schmerling; "Surface Area Measurements. A New Tool for Studying Contact Catalysts," by P. H. Emmett; "The Geometrical Factor in Catalysis," by R. H. Griffith; "The Fischer-Tropsch and Related Processes for Synthesis of Hydrocarbons by Hydrogenation of Carbon Monoxide," by H. H. Storch; "The Catalytic Activation of Hydrogen," by D. D. Eley; "Isomerization of Alkanes," by Herman Pines; and "The Application of X-Ray Diffraction to the Study of Solid Catalysts," by M. H. Jellinek and I. Fankuchen.

All of the articles will be read with much interest. However, the time has not yet arrived when one specifies exact mechanisms for most catalyst reactions. Taylor presents interesting data which indicate hydrogen is chemisorbed on nickel-chromia catalysts, for example, in two different ways—one at a temperature below −78° C and the other above 0° C. He succeeds in adducing much evidence to show the nonuniformity of chemisorption on various surfaces. The other authors likewise provide much new information. Every chapter is written by a specialist in the particular field and the contents are accurately indicated by the titles. A person concerned with catalysis should certainly consult this book.

HENRY EYRING

University of Utah

Detailed atlas of the head and neck. Raymond C. Truex and Carl E. Kellner. New York: Oxford Univ. Press, 1948. Pp. xiii + 162. $15.00.

We find in this atlas an unusually complete coverage of the anatomy of the head and neck. Some eighty of the figures are of dissections and thirty of frontal or transverse sections. In all but a few plates of the skull and vertebrae, the artist has been painstaking and successful in representing by line and shade the finer structure of organs and the texture of tissues. Blood vessels and nerves are in colors. The figures are large, some of them over life size.

An atlas, a chart, or a model may lose much of its value by faulty labeling. This feature has been given careful consideration. Labels are abundant and this abundance is reflected in the extent of the index. The special problem of labeling the closely packed structures of some sections of the head is met by repeating the central part of the plate on the opposite page.

In any atlas that faithfully records anatomical preparations there are inevitable variations from the more usual anatomy. These misleading features are usually passed over in silence. Here they are commented on in the explanatory paragraphs accompanying the plates.

The volume will serve as a highly valuable addition to the working equipment of certain clinical specialists and anatomists. Its contents are too extensive for daily use by the first-year student but it should be made available to him for reference.

JOHN J. SHEININ

Chicago Medical School

Scientific Book Register

BENEDICT, MANSON, and WILLIAMS, CLARKE. (Eds.) ***Engineering developments in the gaseous diffusion process.*** New York: McGraw-Hill, 1949. Pp. xx + 129. (Illustrated.) $1.25.

BENT, ARTHUR CLEVELAND. ***Life histories of North American thrushes, kinglets, and their allies.*** (U. S. National Museum Bull. 196.) Washington, D. C.: Supt. of Documents, U. S. Govt. Prntng. Office, 1949. Pp. viii + 454. (Illustrated.) $1.50.

BURSTEIN, CHARLES L. ***Fundamental considerations in anesthesia.*** New York: Macmillan, 1949. Pp. x + 153. (Illustrated.) $4.00.

DAVIES, OWEN L. (Ed.) ***Statistical methods in research and production: with special reference to the chemical industry.*** (2nd ed., rev.) New York (3): Stechert-Hafner; London and Edinburgh: Oliver & Boyd, 1949. Pp. xi + 292. 28/–.

EDGELL, GEORGE HAROLD. ***The bee hunter.*** Cambridge, Mass.: Harvard Univ. Press, 1949. Pp. 49. (Illustrated.) $2.50.

EDMONDSON, CHARLES HOWARD. ***Seashore treasures.*** Palo Alto, Calif.: Pacific Books, 1949. (Illustrated.) Pp. 144. $3.50.

GRASSE, PIERRE-P. (Ed.) ***Traité de Zoologie: Anatomie, Systématique, Biologie: Onychophores, Tardigrades, Arthropodes, Trilobitomorphes, Chélicérates.*** (Tome VI). Paris (VI^{e}): Masson et Cie, 1949. Pp. 979. (Illustrated.) 5000 fr.

WENTZEL, GREGOR. ***Quantum theory of fields.*** (Translated from the German by Charlotte Houtermans and J. M. Jauch.) New York, London: Interscience, 1949. Pp. ix + 224. $6.00.

WISLER, C. O. and BRATER, E. F. ***Hydrology.*** New York: John Wiley, 1949. Pp. xi + 419. (Illustrated.) $6.00.

NEWS and Notes

Wendell Latimer has resigned as dean of the College of Chemistry at the University of California to devote his full time to nuclear research. Dr. Latimer will be succeeded by **Joel Hildebrand,** who has been both chairman of the Department of Chemistry and dean of the College of Letters and Science.

Alex J. Steigman is now serving as consultant in clinical epidemiology for the National Foundation for Infantile Paralysis, in New York City, where he will conduct field work in early diagnosis, management, and epidemiologic investigations of poliomyelitis. During a recent two-year period as senior fellow in pediatrics with the National Research Council, Dr. Steigman conducted investigations in poliomyelitis at the Children's Hospital Research Foundation, in Cincinnati, Ohio.

Bernard B. Watson, associate professor of physics at Temple University, has been appointed specialist for physics in the Office of Education of the Federal Security Agency.

Paul R. Trumpler, engineer at the centrifugal engineering department of the Clark Brothers Company of Olean, New York, has been appointed professor of mechanical engineering at Illinois Institute of Technology.

John F. Fulton, Sterling Professor of Physiology, has been appointed Rosenbach Fellow in Bibliography for 1949–50 at the University of Pennsylvania. Dr. Fulton will deliver three lectures on "The Great Medical Bibliographers" on February 2, 9, and 16, 1950.

Ward Pigman, head of the organic chemistry group at the Institute of Paper Chemistry, Appleton, Wisconsin, has been appointed associate professor of biochemistry at the Medical College and Dental School of the University of Alabama, Birmingham.

William A. Ritchie, curator of anthropology at the Rochester Museum of Arts and Sciences, has been appointed senior scientist in archaeology at the New York State Science Service and the New York State Museum. Dr. Ritchie is the author of *The pre-Iroquoian occupations of New York State,* which was awarded the A. Cressy Morrison Prize in Natural Science in 1943 by the New York Academy of Science.

James F. Bonner, professor of biology at California Institute of Technology, **Karl Hamner,** University of California plant physiologist, and **William Albrecht,** professor of soil science at the University of Missouri, are attending the Commonwealth Agricultural Specialists Conference in Australia.

F. Gray Butcher, entomologist with the North Dakota Agricultural College, has accepted an appointment as assistant professor of zoology at the University of Miami, Coral Gables. Dr. Butcher will teach courses in economic entomology and conduct research on horticultural pests of the area.

Richard Crutchfield, chairman of the Department of Psychology at Swarthmore College, will spend the academic year as visiting professor at the University of California at Berkeley. **William C. H. Prentice** has been made associate professor and acting chairman of the Swarthmore department.

Visitors to U. S.

D. Hans F. Häusler, of the Department of Pharmacology, University of Graf, Austria, returned home on August 16 after spending three months at medical centers in this country and Canada. Dr. Hausler's visit was sponsored by the Rockefeller Foundation.

Pedro Regules, ear, nose, and throat specialist from Montevideo, is spending a month here. Dr. Regules will visit the army hospitals at Philadelphia and New York.

Recent visitors at the National Bureau of Standards included **K. H. Chen,** instructor at the National Institute of Health, Central Hospital, Nanking, China; **P. M. Millman,** astronomer, Dominion Observatory, Department of Mines and Resources, Ottawa, Canada; **Henrik Nordenfelt,** engineer from Stockholm, Sweden; **Henry G. Sutton,** director, Sutton Tool and Gauge Manufacturing Company, Ltd., Victoria, Australia; **Gilbert Raes,** head of the Textile Laboratory, University of Ghent, Belgium; **J. Shone,** physician with the Ministry of Health, Andrews Memorial Hospital, Kingston, Jamaica; and **Jack Hampton Willis,** advisor on manufacturers' problems, with the Australian Wool Realization Commission, Australia.

George Addison, plant geneticist in the Instituto Agronomico do Norte, Belem, Para, Brazil, is visiting here for six weeks to consult with American geneticists. Mr. Addison will spend a week conferring with officers of the Department of Agriculture in Washington and will then tour northern and eastern states.

Grants and Awards

The American Institute of Nutrition announces that nominations are now being solicited for the 1950 **Mead Johnson and Company B-Complex Award,** the **Borden Award in Nutrition,** and the **Osborne and Mendel Award,** to be presented at the annual meeting of the institute next spring. These three $1,000 awards are made annually.

The Mead Johnson Award is given to the laboratory or clinical research worker in the U. S. or Canada responsible for the publication during the previous calendar year of the best scientific report dealing with the field of the B-complex vitamins. The Borden Award is given to U. S. or Canadian investigators in recognition of distinctive research emphasizing the nutritive significance of milk or dairy product components. It is made primarily for the publication of specific papers but may be given for important contributions over an extended period of time and may be divided between two or more investigators. The Osborne and Mendel Award is given to the investigator who has made the most significant published contribution in

the year preceding the annual meeting or who has published a series of contemporary papers of outstanding merit. All nominations must be in the hands of the Nominating Committee by *January 15, 1950*. The nominations, which can be made by anyone, should be accompanied by data relative to the research of the nominee. Membership in the institute is not a requirement for eligibility.

The National Research Council of Ottawa, Canada, has awarded two **Merck post-doctoral fellowships** in the natural sciences for 1949–50. The grants have been made to D. A. I. Goring, of the Department of Physical Chemistry at McGill University, who will study colloid science at Cambridge University, England; and M. J. Miller, of the Institute of Parasitology at Macdonald College, Canada, who will continue his research in medical parasitology and clinical tropical medicine at the School of Tropical Medicine, University of Calcutta, India.

Smith, Kline and French Laboratories, Philadelphia, has awarded traveling fellowships of $5,000 each to Edward B. Ferguson, Jr., of Tulane University, and Charles J. Kensler, of Cornell University. Dr. Ferguson will study the physiology of the kidney at Cambridge University, and Dr. Kensler will conduct pharmacological research at Oxford University.

Colleges and Universities

The University of Notre Dame's radiation chemistry project, formerly supported in part by the Office of Naval Research, will from now on be operated under the auspices of the Atomic Energy Commission. The project is devoted entirely to solution of fundamental problems in radiation chemistry and will handle none of the technological features involved. Fields now under investigation include the effects of high energy radiation on ionic solids and on organic compounds and solutions, the mechanism of chemical processes involving nuclear recoil, and radiation chemical monitoring. Studies on aqueous systems and protophotosynthesis are planned. Training of workers is an important part of the program. Faculty members who will direct work in the project include Milton Burton, Andrew J. Boyle, William H. Hamill, John L. Magee, and Russell R. Williams, Jr.

The University of Maryland and the **Naval Ordnance Laboratory** will establish an Institute of Fluid Dynamics and Applied Mathematics at the university this fall. Directors of the institute will be Kampe de Ferriet, of the University of Lille, now a consultant to NOL, and Alexander Weinstein, member of the NOL Mechanics Division.

Meetings and Elections

From June 22 to June 28, 1949, the University of Denver was host to a group of physicists who gathered in Idaho Springs, Colorado, near the Inter-University High Altitude Laboratory at Echo Lake, for a **Symposium on Cosmic Rays.** The meeting was remarkable for the attendance, for the number and importance of the papers presented, and, not least, for the excellent organization, due mainly to Profs. Cohn and Iona of the University of Denver.

The discussions centered on four major subjects, namely (1) properties of mesons (discussion leaders: Anderson and Brode); (2) nuclear interactions of cosmic rays (discussion leader: Rossi); (3) primary radiation (discussion leaders: Wheeler and Schein); and (4) air showers (discussion leaders: Bethe and Greisen). Reports on previous investigations concerning these various subjects had been prepared by the discussion leaders and distributed to the participants, so that the work of the conference could be focused on the most recent developments.

During the discussion on the properties of mesons, Barkas reviewed the results obtained at Berkeley on mesons produced artificially by means of the cyclotron and the synchrotron. He presented tentative data on cross sections for meson production by α-particles, protons, neutrons, and γ-rays of different energies, as well as the latest values for the masses of the π- and the μ-meson (215 and 285 electron masses respectively) and for the mean life of the μ-meson (0.63×10^{-8} sec). Among the results concerning "natural" μ-mesons, one may mention a new mass determination by Anderson, based upon the measurement of the maximum energy of their decay electrons, which gave a value of 217 electron masses.

Much of the discussion on nuclear interactions of cosmic rays centered on such questions as the cross sections of various elements for these interactions and the nature of the secondary products. Many of the physicists attending the meeting described new experimental results, obtained at mountain altitudes or with balloon and rocket experiments and bearing more or less directly on these questions. During the discussion, a number of interesting and spectacular pictures were presented, obtained both with the cloud chamber method and by means of the newly developed photographic emulsions that are sensitive to particles with minimum ionization. Some remarkable pictures by Peters and Bradt were presented, showing the disruption of heavy primary cosmic ray particles in their collisions with nuclei of elements contained in photographic emulsions and some cloud chamber pictures of Tinlot and Gregory, showing the production of high energy photons in the interactions of cosmic ray neutrons with nuclei of lead and aluminum.

The first part of the discussion on the primary radiation concerned geomagnetic effects, with special emphasis on the latitude variation of the nucleonic component of cosmic rays and of the heavy primary particles. The second part of the discussion dealt mostly with experimental results on the nature of primary cosmic rays obtained by means of rocket and balloon experiments. From these results it appears that between 80 and 90 percent of the primary rays are protons, the rest being heavier nuclei, mainly helium nuclei (Peters, Nye). No appreciable number of electrons or photons seem to be present in the primary radiation Hulsizer, Nye).

During the discussion on air showers, Cocconi and others described recent experimental results concerning the relative abundance

and the spatial distribution of the various kinds of particles (electrons, mesons, nucleons) that form these showers. Blatt presented some new developments in the theory of the lateral distribution of the electronic component. Bethe suggested a tentative theoretical picture for the development of an air shower, describing it as a chain of nuclear interactions initiated by the arrival upon the atmosphere of an extremely energetic proton. Each nuclear interaction gives rise to several secondary nucleons, π-mesons, and neutral mesons. The neutral mesons immediately decay into photons, which then undergo cascade multiplication.

BRUNO ROSSI

The Society for Applied Spectroscopy will meet October 4 at 8 p.m. at the Socony-Vacuum Training Center, 63 Park Row, New York City. Ralph H. Muller, of New York University, will speak on "Instrumental Methods of Analysis."

The 34th Annual Meeting of the Optical Society of America will be held at the Hotel Statler, Buffalo, New York, on October 27–29, 1949. The program includes a symposium on microscopy and invited papers on the following subjects: "Electron Microscopy," by L. Marton, National Bureau of Standards; "Infrared and Raman Spectra of Crystals," by Donald F. Horning, Brown University; "Analysis of Segregates in Alloys," by J. Convey, Canadian Bureau of Mines; "Spectrochemical Research in the Union of South Africa," by A. Strasheim, National Physical Laboratory, Pretoria, South Africa; "The Eye and the Camera," by George Wald, Harvard University; and "High Precision Measurements with Simple Equipment," by A. C. S. van Heel, Technical University, Delft, Holland.

A conference on mechanisms and evaluation of antiseptic activity will be held in New York City October 28–29 under the auspices of the Biology Section of the New York Academy of Sciences. The Friday afternoon sessions will be devoted to the antibiotics, Friday evening to quaternary ammonium compounds and other chemicals characterized by high surface activity, and Saturday morning to the halogens, mercurials, alcohols, and other agents, as well as high temperature. Attendance will be limited to members of the academy and invited guests. Scientists interested in participating may obtain further information from Mrs. Eunice Thomas Miner, Executive Director, New York Academy of Sciences, Central Park West at 79th Street, New York 24, New York.

The Second Annual Nucleonics Symposium, sponsored by the Institute of Radio Engineers and the American Institute of Electrical Engineers, will be held at the Hotel Commodore in New York City on October 31–November 2. The program will include a round-table discussion on "Evaluation of Radiation Hazards," and an address by Karl T. Compton, chairman of the Research and Development Board of the National Military Establishment.

The Fluid Dynamics Division of the American Physical Society will hold a symposium at the University of Virginia December 28–30 on "Irreversible Processes in Fluid Dynamics." Five half-day sessions will be devoted to energy transport and exchange, viscous and plastic flows, mass transport and fluctuation, entropy changes in irreversible processes, and energy transfers in shock, flame, and detonation fronts. In addition there will be one half-day session for contributed papers. Requests for accommodations by nonmembers should be sent to the Secretary, School of Physics, Rouss Physical Laboratory, University of Virginia, Charlottesville, Virginia, as soon as possible.

The Chemistry Section of the AAAS will hold its annual meeting in New York City on Friday and Saturday, December 30 and 31, in the Statler Hotel. Two symposia are being planned, one by George Glocker, of the State University of Iowa, on "Progress in Chemistry," and another by Robert S. Shelton, of the William S. Merrel Company, on "Some Recent Advances in Medicinal Chemistry." Papers for a general session are solicited. Titles and abstracts should be sent to Dr. E. F. Degering, Department of Chemistry and Chemical Engineering, Armour Research Foundation, Technology Center, Chicago 16, on or before *October 1*.

The American Society of Mammalogists, at its 29th annual meeting in Washington, D. C., elected the following officers: president, Tracy I. Storer, University of California; vice-presidents, Lee R. Dice, University of Michigan, and William J. Hamilton, Jr., Cornell University; corresponding secretary, Donald F. Hoffmeister, University of Illinois; recording secretary, Robert T. Orr, California Academy of Science; treasurer, Viola S. Schantz, U. S. Fish and Wildlife Service; and editor, William H. Burt, University of Michigan.

At a recent meeting of the Board of Trustees of the **Worcester Foundation for Experimental Biology,** Charles B. Huggins, professor of surgery at the University of Chicago, George W. Calver, of the U. S. Navy, and Ralph F. Gow, executive vice-president of the Norton Company were elected trustees for a term of four years.

The American Society for Metals has elected the following officers for the coming year: president, Arthur E. Focke, research metallurgist for the Diamond Chain Company, Indianapolis, Indiana; vice president, Walter E. Jominy, staff engineer at the Chrysler Corporation.

Deaths

George Hugh Henderson, 56, O. E. Smith Professor of Physics, Dalhousie University, Halifax, Nova Scotia, died on June 19 en route to New Brunswick on a fishing trip. Professor Henderson was well known for his researches in radioactivity and in the study of pleochroic halos. He was a fellow of the Royal Society of London and of the Royal Society of Canada.

Carlos G. Bates, 64, a fellow of the Society of American Foresters and veteran of 42 years of research work in the U. S. Forest Service, died

of a heart attack at his home in St. Paul on July 22. Since 1928 Dr. Bates had been attached to the Lake States Forest Experiment Station in St. Paul.

Donche Kostov, 52, biologist, died at his home in Sofia, Bulgaria on August 10 after a long illness. He had been working on a Bulgarian translation of the works of Michurin, the Soviet biologist, at the request of the Bulgarian government.

John Frederick Speck, 29, research associate in the Department of Biochemistry at the University of Chicago, died August 18 in an accident while mountain climbing in the French-Italian Alps. Dr. Speck was on leave of absence from the University of Chicago and had been a Rockefeller Fellow in the Nobel Institute at Stockholm, Sweden, since last fall.

Frank Thone, 58, biology editor of Science Service, died August 25 of a heart attack in Washington, D. C. A specialist in plant ecology, Dr. Thone joined the staff of Science Service in 1924. In 1946 he received a Westinghouse award for distinguished science writing. He was the author of *Trees and flowers of Yellowstone National Park* and *The microscopic world.*

A new periodical, *Angiology, The Journal of Peripheral Vascular Diseases,* will begin publication in February 1950. Saul S. Samuels, chief of the Department of Peripheral Arterial Diseases, Stuyvesant Polyclinic Hospital, New York City, will be editor-in-chief. Among associate editors in the U. S. are Alton Ochsnev, of Tulane University; Keith Grimson, of Duke University; Leo Loewe, of Long Island Medical College; D. W. Kramer, of Jefferson Medical College; and Gerald Pratt, of New York University Medical School. The journal will be published by the Williams and Wilkins Company and sold at a subscription price of $8.00 a year.

The Japanese Journal of Experimental Medicine, which, until it ceased publication in October 1941, was the most important English language journal of Japanese medicine, resumed publication with Volume 20, No. 1, March 1, 1949. The Army Medical Library has a few extra copies of this volume for distribution upon request to interested libraries that did not receive it.

Recently Received—

Research Today: New Research in Antibiotics. (Spring issue.) Issued by Lilly Research Laboratories, Eli Lilly and Company, Indianapolis 6, Ind.

Critical Requirements for Research Personnel: A Study of Observed Behaviors of Personnel in Research Laboratories. American Institute for Research, Pittsburgh, Pa.

Fishery Statistics of the United States 1945. (Statistical Digest No. 18, Fish and Wildlife Service, published in 1949.) For sale by Supt. of Documents, U. S. Government Printing Office, Washington 25, D. C. at $1.50.

Symposium on Thermodynamics. (Sponsored by the International Union of Pure and Applied Physics. Held in Brussels, January 1948.) In French and English. Printed by J. & R. Sennac, Paris IX^{e}, France.

Studies in Experimental Zoology: Regeneration, Experimental Embryology, Endocrinology by A. Elizabeth Adams. (3rd. ed.) Order from Edwards Brothers, Inc., Ann Arbor, Mich.

Anais da Associação Química do Brasil. Publicados trimestralmente by Associacao Quimica do Brasil, Caixa, 1815, S. Paulo, Brazil.

Institute of Metals (reprints from March 1949 *Journal*): Constitution of Aluminum-Copper-Magnesium Alloys; Crystallite Theory of Strength of Metals; Relation between the Degree of Order and the Lattice Parameter of Cu_3Au; and Pure Platinum, of High Recrystallization Temperature, Produced by Power Metallurgy. Institute of Metals, London (S.W.1), England.

Tables of Scattering Functions for Spherical Particles (National Bureau of Standards Applied Mathematics Series #4). Obtainable from Supt. of Documents, U. S. Government Printing Office, Washington 25, D. C. 45¢ a copy.

Diet in Relation to Reproduction and the Viability of the Young (Part I): Rats and Other Laboratory Animals, by F. C. Russell. (Commonwealth Bureau of Animal Nutrition, tech. comm. 16.) Order from Central Sales Branch, Commonwealth Agricultural Bureaux, Penglais, Aberystwyth, Gt. Britain. Price 6/– sterling.

List of Scientific Papers published in the Middle East, compiled by Unesco's Science Cooperation Office, Cairo, Egypt.

Bibliography on Sprays by Kalman J. DeJuhasz. Published by The Texas Company, Refining Dept., Technical and Research Div., 135 E. 42nd Street, N. Y.

Make Plans for—

The Board of Governors of the National Speleological Society will meet October 1 at the American Museum of Natural History, New York City.

Electron Microscope Society of America, annual meeting, October 6–8, National Bureau of Standards, Washington, D. C.

Society of American Foresters national meeting, October 11–13, Olympic Hotel, Seattle, Washington.

American Standards Society, 31st annual meeting, October 11–14, Waldorf-Astoria Hotel, New York City.

Electrochemical Society, 96th annual convention, October 12–15, La Salle Hotel, Chicago, Illinois.

Correction: It was erroneously stated in the August 26 issue of *Science* (p. 220) that the December 29 AAAS symposium on *Botany in the Service of Mankind* would be held at the Hotel Statler. The session will be held in the Winter Garden of the Hotel McAlpin.